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Arnold Schwarzenegger
Governor

2 April 2009

Ms. Mary K. Snyder
District Engineer
Sacramento Regional County Sanitation District
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ACCEPTANCE OF SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT'S DYNAMIC MATHEMATICAL MODEL FOR USE IN NPDES PERMIT RENEWAL FOR THE SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT

Regional Water Board staff accepts the Sacramento Regional County Sanitation District's (District) dynamic mathematical model for use in the NPDES permit renewal for the Sacramento Regional Wastewater Treatment Plant. Staff will use results from the District's model to develop water quality-based effluent limitations and for the anti-degradation analysis to address the District's requested discharge capacity increase. Water Board staff will continue to review the models, data input and calculated output through permit development and the public comment process. Final acceptance of the dynamic mathematical model, however, will be made by the Regional Water Board after public comments have been considered.

The District's dynamic model consists of several linked mathematical models. The linked models include:

- FLOWMOD (3-D dilution model used for near-field modeling)
- DYNTOX (Monte Carlo model used in near-field modeling)
- Longitudinal Dispersion Model (LDM) (used to model double–dosing effects in near field)
- Fischer Delta Model (FDM) (hydrodynamic and water quality model used for near and far field modeling)

Regional Water Board staff has worked with District staff on the review and validation of these modeling tools since 2001. In the period from 2005 through 2007, the District performed several field validation studies to corroborate the effectiveness of the modeling tools in representing water quality conditions in the Sacramento River. Due to the complexity of the mathematical models, in 2006 the Regional Water Board used the services of Tetra Tech, a USEPA contractor, to assist with the review of the dynamic model. Tetra Tech concluded that the model study was conducted in a sound and scientifically defensible manner. The model experts determined that the linked dynamic modeling system is capable of providing an accurate probabilistic representation of receiving water quality conditions. The only perceived short coming noted by the model experts from a regulatory perspective was the complexity of the system of linked models and the proprietary status of some of the model components preventing its transmittal and direct use by Regional Water Board staff. The results of Tetra Tech's review are summarized in the enclosed Tetra Tech memorandum dated 30 June 2008.

Based on the results of the extensive reviews and validation studies that have been performed, Regional Water Board staff will proceed to use the District's modeling tools for the NPDES permit renewal process. Specifically, the tools are judged to be suitable for use in the dynamic near field modeling of the District's discharge and the derivation of water quality-based effluent limits (WQBELs). Use of the dynamic modeling approach for derivation of WQBELs is specifically authorized in the State Implementation Plan (SIP) and in the USEPA Technical Support Document (TSD) for Water Quality-based Toxics Control.

The modeling tools are also judged to be suitable for use in the near and far field water quality impact analysis performed as an element of the antidegradation analysis. The tools are appropriate to assess the magnitude of incremental water quality impacts of the proposed expanded discharge to the Sacramento River.

Regional Water Board staff will continue to work with District staff in the application of these modeling tools. It will continue to be important to maintain a transparent approach to allow an appropriate level of review by third parties interested in the District's permit renewal.

If you have any questions regarding this letter, please contact me at (916) 464-4726 or klandau@waterboards.ca.gov.

KENNETH D. LANDAU
Assistant Executive Officer

Enclosure (1)

Tetra Tech, Inc.
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Final Memorandum

Date: June 30, 2008

From: John Hamrick, Ph.D., P.E., D.WRE
Jon Butcher, Ph.D., P.H.

To: James D. Marshall, P.E.
Senior Water Resources Control Engineer
Central Valley Regional Water Quality Control Board
11020 Sun Center Dr. Suite 200
Rancho Cordova, CA 95670

Cc: John Craig (Tetra Tech), David Carlson (CVRWQCD),
Jim Parker (PG Environmental), Mark Flachsbart, EPA

Subject: Review of the Sacramento Regional County Sanitation District's Dynamic Modeling Study for the Sacramento Regional Wastewater Treatment Plant

1. Introduction

This document completes Tetra Tech's review of Sacramento Regional County Sanitation District's (SRCSD) dynamic modeling study to support the Draft Environmental Impact Report (Draft EIR) for the for the Sacramento Regional Wastewater Treatment Plant (SRWTP) 2020 Master Plan (SRCSD, 2003). The review considers water quality modeling documentation presented in the Draft EIR, subsequent comments by the Central Valley Regional Water Quality Control Board (CVRWQCB) and corresponding responses and submissions by SCRSD. Specific attention was focused on comments and responses requiring additional submissions by SRCSD. These submissions, summarized in the following section, addressed specific components of the dynamic modeling framework including Flow Sciences' longitudinal dispersion model (LDM) and FLOWMOD diffuser model, and the DYNTOX dynamic mixing model. The review of LDM and FLOWMOD related submissions were conducted John Hamrick, while the review of DYNTOX was conducted by Jon Butcher. The organization of the memorandum is as follow. Section 2 provides a brief review of the overall dynamic modeling framework considering material from the Draft EIR and subsequent comments by CVRWQCB and responses from SRCSD. A number of issues were not fully resolved in this exchange and additional issues were identified in the course of this review. Both categories required additional clarifications, analyses, field investigations, modeling, or combinations hereof on the part of SRCSD and subsequent submission for review. The next three sections, Sections 3, 4, and 5, summarize the reviews of submissions related to the LDM, FLOWMOD, and DYNTOX models. Conclusions and recommendations for the entire review process are presented in Section 6 with references listed in Section 7. Attachment A includes copies intermediate memorandums submitted by Tetra Tech. Attachment B provides an index of the electronic document file for the review which was provided by Tetra Tech to CVRWQCB.

2. Review of the Overall Dynamic Modeling Framework

Initial review of the dynamic modeling framework employed for water quality modeling in support of impact assessment included the following material

Draft EIR Appendices F, G, H, and I. (Appendix F, which describes modeling is dated July 2002) Files: EIR-Appendix F*.pdf –I*.pdf

Letter from Karen Niiya to Patricia Leary dated 14 April 2005 summarizing CVRWQCB comments on modeling in EIS.
File: 2005_04_14NiiyaModelingMemo.doc

CVRWQCB Comments and SRCSD Responses. Three response Tables.
Files: ResponseTable1of3.doc, Response Table 2 of 3 reorganized.doc, ResponseTable3of3.doc

Summary of Models Table. File: SummaryofModel.doc

where *.doc and *.pdf documents reference actual file names in the electronic document file of material reviewed, Attachment B. The overall modeling framework and the application of the individual models are documented in Appendices F-I of the Draft EIR (SCRSD, 2003). CVRWQCB comments on material in the EIR are in the 'Letter', while SRCSD responses and summary descriptions of the models are contained in the last two documents.

The framework utilizes a sequence of models and analyses to develop a hybrid approach combining continuous simulation of river and effluent flows with Monte Carlo derived ambient river and effluent water quality concentrations, all at a one hour time scale. The U.S. Bureau of Reclamation Project Simulation Model (PROSIM) was used to simulate a 70-year (1922-1991), inclusive hydrologic period of record. The model can consider alternative operations of the Central Valley Project (CVP) and the State Water Project (SWP), as well as current and future hydrology based on existing and projected land uses can be input into the model to characterize existing and future reservoir operations, river flows, Delta inflow, etc. Given the highly controlled nature of the SWP and CVP only monthly average flows in the Sacramento River are output. The Sacramento River at Freeport is tidally influenced and can exhibit significant variations in flow, including flow reversal, at hourly time scales, thus the dynamic modeling was conducted at an hourly time scale. Hourly flows at Freeport were generated using the Fischer Delta Model (FDM), a hydrodynamic and transport model representing the one-dimensional channel network of the Sacramento and San Joaquin Delta. Downstream boundary conditions for the FDM were historical hourly tidal water surface elevation, while upstream boundary conditions were monthly river flows from PROSIM. It was presumed that the downstream boundary was below the confluence of the Sacramento and San Joaquin River and upstream boundaries were far enough such that tidally influenced flow at Freeport was not influenced by false tidal wave reflection. Although documentation refers to this use of boundary conditions having disparate time as disaggregation of monthly river flows, it is simply a combination of model boundary conditions having two distinct scales and is not unusual in that most estuary and tidal river models use daily river flows as upstream boundary conditions. As noted, the combination of a highly controlled system and a 70 year simulation make monthly flows acceptable. This is further enforced by the fact that high event flows, which provide correspondingly high effluent dilution, pose no likelihood of water quality criteria violation. The more critical low drought condition flows typically persist for weeks to months, particularly in regulated river basins such as the central valley, where minimum flows are maintained. The application of the PROSIM and FDM are well documented in the Draft EIR, including enhanced calibration and validation of FDM in the vicinity of Freeport. The only comment by CVRWQCB specific to these two models, comment J1, requiring clarification was the method of specifying the downstream tidal boundary condition which was resolved in a response by SCRSD.

The FDM predicted hourly flows at Freeport are used in conjunction with the one-dimensional longitudinal dispersion model (LDM) and the three-dimensional FLOMOD near-field diffuser model to predict discharged effluent concentration in the Sacramento River downstream of the SRWTP diffuser. The LDM is based an analytical solution of the one-dimensional, unsteady advection diffusion equation. The flow velocity and the longitudinal dispersion coefficient are assumed to be spatially constant but varying in time. The LDM can simulate the transport of cross-sectional mixed material, having an arbitrary spatially varying initial condition, along the river at time scales well less than one hour and thus resolve tidal influences including flow reversal. FLOWMOD is a three-dimensional steady state computational fluid dynamics model base on solution of the Reynolds averaged Navier-Stokes (RANS) equation. FLOWMOD is used to simulate steady state approximations to the instantaneous discharge and mixing of effluent from the SRWTP diffuser at spatial scales on the order of a few feet. Since the time scale for the three-dimensional diffuser induced flow to reach steady state in response to tide induced changes in river flow is much smaller that the time scale for tide induced changes, using FLOWMOD to simulate the anticipated range of river and effluent flows as equivalent steady states is justified.

The need to use LDM in conjunction with FLOWMOD arises during periods of flow reversal. Operational rules for the diffuser require discharge to cease when river flow drops below 14 times the effluent flow, including periods of reverse flow. Plant effluent which would normally be discharged is held in a storage basin and subsequently discharged with the renewed effluent flow when the river flow becomes greater than 14 times this total or combined flow. When flow reversal occurs, effluent previously discharged downstream of the diffuser may be transported upstream of the diffuser. When the flow reversal ends and diffuser discharge begins anew, so-called double dosing can occur with the ambient river concentration including a contribution from previously discharged effluent. In principle, the FDM could be used to simulate the transport of effluent upstream of the diffuser during periods of flow reversal. However the longitudinal resolution of the FDM in the vicinity of Freeport is too coarse to resolve spatial variation in effluent concentration just before, during, and after a flow reversal event. Instead of spatially refining the FDM, which would impact it run time performance efficiency, the LDM model was developed such that it could efficiently account for double dosing at the appropriate space and time scales.

The LDM and FLOWMOD models were applied to simulate effluent dilution in the river under a wide range of river and effluent flow conditions to develop a response matrix capable of accurately providing an effluent dilution for every combination of hourly scale river and effluent flows in the 70 year simulation period. The use of the response matrix was validated by direct application of the two models for randomly selected river and plant effluent flow combinations. This simulation approach can be viewed as a deterministic continuous simulation using synthesized river and effluent flow projection. The final component of the modeling framework was the use of the DYNTOX model to estimate statistical distributions of water quality conditions in the near-field zone, downstream of the SRWTP diffuser, over a wide range of conditions. This particular DYNTOX application was unique in that continuous river and effluent flows and associated dilutions were combined with probabilistic generated ambient and effluent water quality conditions. The use of probabilistically generated concentrations is necessary to produce a corresponding 70 year continuous record based on statistical properties determined form much shorter monitor data records. When both the flows and associated water quality constituent concentrations are probabilistically based, the approach is referred to as Monte Carlo simulation. In this case, the approach is a combination of continuous simulation for flow and dilution and Monte Carlo for water quality constituent concentrations in that concentrations are randomly generate to conform with data defined probability distributions

The CVRWQCB provided extensive comments to SRCSD regarding the application of LDM and FLOWMOD. Although many of the comments were resolved in the SRCSD responses, additional submissions were required. The unresolved comments/responses and resulting submissions focused on the broad area of model accuracy including calibration, validation, sensitivity, and uncertainty. These submittals included the results of sensitivity analyses for both LDM and FLOWMOD. Additionally for FLOWMOD, three field dye studies were conducted during 2005 and 2006 and used for further validation of FLOMOD. Further discussion and review of LDM and FLOWMOD are presented in the following two sections, respectively. Since the application of the DYNTOX model in this study was somewhat unique in combining aspects of continuous simulation and Monte Carlo type simulation, the DYNTOX modeling was independently reviewed and a new round of comments and responses with SRCSD was initiated. These comments and responses are included in Attachment A and their final resolution summarized in Section 5.

3. Review of the Longitudinal Dispersion Model (LDM) and Sensitivity Analysis

The Longitudinal Dispersion Model (LDM) is used to simulated reverse flow events in the Sacramento River in the vicinity of the SRWTP discharge. During reverse flow, previously discharged effluent mixed with river water is transport upstream of the diffuser. Discharge through the diffuser ceases just before and during reverse flow. When normal downstream directed flow resumes and reaches a magnitude of 14 times the permitted effluent flow, effluent discharge resumes. During the time interval required for previously upstream transport water to pass back downstream over the diffuser, ambient river water quality conditions include contributions from previously discharged effluent constituents. This phenomenon, often referred to as double dosing, is common in tidal environments. As noted in the preceding section, the FDM's water quality component could have been used to simulate upstream effluent transport during reverse flow events at the expense of having to highly refine its spatial resolution in the vicinity of the diffuser. The LDM was implemented as an alternative to refinement of the FDM. The LDM is based on the one-dimensional advection-dispersion equation

$$\frac{\partial C}{\partial t}+U\frac{\partial C}{\partial x}=E\frac{\partial^2 C}{\partial x^2} \qquad (1)$$

where C is the cross sectional average concentration, U is the cross sectional average velocity and E is the longitudinal dispersion coefficient. The longitudinal dispersion coefficient accounts for the enhanced longitudinal spreading of material relative to the mean advection velocity, due to the interaction differential advection and transverse mixing. Functionally E has the general form

$$\frac{E}{HU}=f\left(\frac{U_*}{U},\frac{H}{B},\frac{T_pU}{H},\frac{B}{R}\right) \qquad (2)$$

representing the product of a length and velocity scale which depends on the shear velocity, channel cross-sectional geometry represented by the depth H, and width B, channel path curvature, R, and tidal period T_p. Although a number of predictive formulas for E are available, site specific field measurement are preferred. The form of the advection dispersion equation and the analytical solution used as the basis of the LDM model require U and E to be assumed independent of the longitudinal or along river coordinate x, which is reasonable if cross section characteristics do not vary significantly in the region of application. For application of the LDM, the cross sectional average velocity in the vicinity of the diffuser is provide by the FDM. The analytical solution used in the LDM further assumes that over a time step Δt, U and E are constant. Time evolution of the concentration field is predicted by reinitializing the analytical solution as U and E change. The temporal variation in the longitudinal dispersion coefficient E, is assumed to follow that of the velocity U. Although a numerical solution of (1) could have be used, allowing the assumption of spatially constant U and E to be relaxed, the analytical solution eliminates fictitious numerical dispersion allowing the exact impact of variations in the magnitude of E to be evaluated.

The primary comments by CVRWQCB on the LDM related to operational aspects of its use for reverse flow events, the appropriateness of the chose longitudinal dispersion coefficient, and the lack of actual calibration and validation of LDM predictions. These issues were addressed by SRCSD in response to comments and further addressed in the report

> Flow Science Incorporated (2006a). Results of Longitudinal Dispersion Model of Worst Case Reverse Flow Events. Prepared for FRWA and SRCSD. (electronic document file document FRWA SRCSD Report 8-18-06.pdf)

This report describes in detail the application of the LDM model for reverse flow events, specifically addressing the potential impact of the proposed FRWA intake upstream of the diffuser. The rationale for not conducting a formal calibration and validation of the LDM model, which would require one or more field dye releases during actual reverse flow events, is also discussed. In the calibration and validation approach, a first dye release would be necessary to calibrate the model with respect to the range of dispersion coefficients expected during a period of unsteady flow. A subsequent dye release during a reverse flow event would be conducted to validate the dispersion coefficient range defined by the calibration. In lieu of conducting a calibration dye release, an initial estimate of the dispersion coefficient was base on a historical study in another region of the Sacramento River. This estimate was used in conjunction with other literature ranges to estimate a likely range of dispersion coefficients, 20 to 110 ft^2/sec, corresponding to E equal 7.1 HU, that would be expected during a reverse flow event. This range of dispersion coefficients was used for LDM results reported in the EIR. The report presented evidence that a reverse flow event was unlikely to occur in the near future eliminating the possibility of field dye study based validation. Under these circumstances, a sensitivity analysis provides an alternative to calibration and validation if the analysis demonstrates an acceptably low level of sensitivity of model predictions to a bounding range of dispersion coefficients.

Appendix A of FSI (2006a) presents the results of such a sensitivity analysis. The sensitivity analysis is based on selection of a low range, 5 to 20 ft^2/sec, and a high range, 40 to 500 ft^2/sec, of dispersion coefficients to supplement the base range of 20 to 110 ft^2/sec. The low range represents an extreme low bound for a large river such as the Sacramento and could be viewed as close to a limiting case of no dispersion, noting that the analytical solution upon which the LDM is based is valid only for non-zero dispersion coefficients. The high range, in particular the maximum value of 500 represents a reasonable up scaling uncertainty factor of more than four times the maximum medium range value. The sensitivity analysis involved simulating 15 representative reverse flow events, spanning the range expected in the 70 year continuous simulation scenario, using each of the three ranges of dispersion coefficients. This data base was then used with the 70 record for river and effluent flow rates to construct 70 records of composite effluent concentration records at locations downstream of the diffuser for each of the dispersion coefficient ranges. Comparison of the three results showed minimal variations between the three dispersion coefficient ranges and that variations were associated with low effluent concentrations or conditions when water quality criteria were not likely to be violated. This sensitivity analysis successfully shows that large uncertainty in the exact magnitude range of the longitudinal dispersion coefficient does not translate into correspondingly large variations in model predictions. Although a more detailed theoretical discussion the dynamics underlying these results is beyond the scope of this section, the results of the sensitivity analysis indicates that from a transport mechanism perspective, advective transport by the cross sectional mean velocity dominates dispersion on the spatial and temporal time scales characterizing reverse flow events.

4. Review of the FLOWMOD Diffuser Model, Sensitivity Analysis, and Field Dye Study Based Validations

The FLOWMOD model is a three-dimensional Reynolds averaged Navier-Stokes equation based model that is used to simulate near-field mixing of the effluent discharged from the SRWTP's multiport diffuser. FLOWMOD represents a higher or more fundamental level of fluid flow modeling in that it involves no reduction in spatial dimensions and no external specification of parameters to quantify turbulent mixing processes. From this perspective, calibration of the FLOWMOD application to the Sacramento River involves only the specification the model resolution scale and the model domain geometry based on observed and/or estimated river bathymetry and surface elevation for specific river flow rates. The primary assumption made in the FLOWMOD application is that time varying river and effluent discharge conditions can be represented by a sequence of hourly steady state conditions. During low and moderate net or daily average river flow conditions in the Sacramento River at Freeport, tidal effects can result in significant flow rate variability over the course of semi-diurnal and diurnal cycles, occasionally resulting in flow reversal. The justification for application of FLOWMOD in steady state mode requires that the response time to changes in flow conditions in the model domain be significantly less that semi-diurnal acceleration time scale of approximately two hours, or on the range of 10 to 20 minutes. The longitudinal extent of the FLOWMOD domain is approximately 800 ft, corresponding to an advective response time of 800/U, where U is the cross sectional averaged longitudinal velocity. For U on the order of 1 ft/sec, the advective response time is much less than semi-diurnal acceleration time scale and the steady state application mode for FLOWMOD is appropriate.

Primary concerns with the application of FLOWMOD include sensitivity of the results to spatial resolution, river bottom bathymetry, and upstream inflow velocity distribution as well a general issue regarding calibration, validation, and uncertainty. Sensitivity issues were addressed in the report

> Flow Science Incorporated (2006b). Model Sensitivity Analysis for FLOWMOD Simulations of the SRCSD Effluent Discharge into the Sacramento River at Freeport, CA. Prepared for SRCSD. (electronic document file document Report Sensitivity Analysis 9-15-06.pdf)

The report is composed of two primary sections addressing model validation and sensitivity analyses. The validation section, which could also be referred to as a revised calibration and validation, presents FLOWMOD simulations of two field dye studies conducted in August 1991 and January 1992. The model results presented are revisions of early results in that the entire width of the river is simulated were as the early results were base of half river width simulation due to limits in computational resources. These simulations also provide the basis for the sensitivity analysis presented in the subsequent section. River flow rates varied during both dye studies, with flow rates during the January or winter period being larger than those during the August or summer period. There were also significant differences in the river bottom bathymetry downstream for the diffuser with the winter conditions being more variable and referred to a rougher in the EIR. Model calibration and validation involved comparison of model predictions and observations dye concentration along three longitudinal transects downstream of the diffuser for six different flow rate for each study. Comparison were essentially visual and qualitative, based on longitudinal-vertical plane contour plots of observed and predicted dye concentrations. Overall, model predictions compared favorably with observations and the model captured the primary features of the mixing region downstream of the diffuser for both the summer and winter conditions. No basic FLOWMOD model parameters were adjusted or calibrated between the two conditions other than the use of two time specific bathymetry sets. The lack of quantitative comparison of model predictions and observations could have been better explained in the discussion. However it is noted that the evaluation of quantitative comparisons of discrete space-time point observations with equivalent steady-state spatial point predictions is difficult to evaluate unless variability of the observations has been quantified, which was not done in this study.

Since FLOWMOD represents the multi-port diffuser as a volume and momentum line source with corresponding discrete fluxes into model grid cells, the selected grid cell sizes influence model predicted concentration and dilution. In this respect, grid cell sizes can be viewed as calibration parameters or require sensitivity analysis to demonstrate that further refinement does not significantly change model results. Sensitivity FLOWMOD predictions with respect to grid cell size was evaluated by halving cell sizes which in effect replace every cell in the base model grid with eight cells in the finer sensitivity grid. Visual comparisons of longitudinal-vertical section concentration contour plots for selected summer and winter conditions for the base and finer grid show negligible differences indicating that the base level of spatial resolution is appropriate. The sensitivity analysis are addresses a number of other issues including the upstream inflowing velocity profile, the dilution level used to define the plume extent, and the difference between simple arithmetic and flux weighed averaging. For the upstream inflow velocity profile, model simulations show little difference between a uniform inflow profile and a cross section variable profile as would be expected since there is approximately 100 ft of longitudinal model domain upstream of the diffuser available for the uniform profile to reach a local equilibrium. With respect to the dilution level used to define the plume boundary, model simulations show decreasing difference between dilutions boundary ranges form 100 to 1000 going downstream of the diffuser. The final sensitivity study indicated that at specific cross sections downstream of the diffuser, flux weighted average concentrations are lower that simple arithmetic averaged used in the EIR. Since flux weight concentrations are preferred from a regulatory perspective, arithmetic averages can be viewed as conservative.

In an unprecedented effort to further demonstrate the validity of the FLOWMOD diffuser model three additional field dye studies were conducted and documented in the following reports

Flow Science Incorporated (2006d). Model Verification Results for FLOMOD Simulations of SRCSD Effluent Discharge to the Sacramento River at Freeport, October 2005 Field Study. Prepared for SRCSD. (electronic document file document Oct06_4_FLOWMOD Validation_October2005_.pdf)

Flow Science Incorporated (2006f). Model Verification Results for FLOMOD Simulations of SRCSD Effluent Discharge to the Sacramento River at Freeport, June 2006 Field Study. Prepared for SRCSD. (electronic document file document FLOWMOD Validation June 06.pdf)

Flow Science Incorporated (2007b). Model Verification Results for FLOMOD Simulations of SRCSD Effluent Discharge to the Sacramento River at Freeport, November 2006 Field Study. Prepared for SRCSD. (electronic document file document November 2006 FLOWMOD_Validation_Fall2006_final.pdf)

and associated data reports listed in Attachment B. The studies were also significant in that detailed bathymetric surveys were conducted to define current river geometry and provide a baseline for any subsequent studies. The general procedure for the field investigation was to discharge a constant dye concentration through the diffuser and measure resulting dye concentrations across six cross sections located 30, 60, 100, 175, 350, and 700 feet downstream of the diffuser. The river discharge changed on an approximate semi-diurnal time scale during the course of the three dye releases. To compare model predictions with observations, six or seven steady state simulation with different river flow rates were conducted for each dye study and the model predictions for specific simulation were compared with observations at downstream cross sections that were sampled at or very near the times of the corresponding flow rates. Visual comparisons were then made between lateral-vertical section contour plots of observed and predicted concentrations. In general the comparisons were acceptable, but not as visually pleasing as the longitudinal-vertical section comparisons used for the 1991 and 1992 comparisons. Some phenomena were observed in the field that were not reproduced in the model, most notably a region of high dye concentration near the eastern river bank just downstream form the diffuser in the October 2005 dye release. The subsequent November 2006 dye release was conducted in an effort to further resolve this observed behavior, however the model failed in all cases to reproduce this high concentration region. Potential explanations for the observed dye behavior include a separation-recirculation zone influenced by the unsteady field flow conditions which are not simulated in the steady state FLOWMOD applications.

5. Review of the Application of the DYNTOX Mixing Model

The DYNTOX model is a dynamic mixing zone model which allows continuous and Monte Carlo base effluent and dilutions flows and concentrations to be combined to produce statistical description of resulting water quality conditions. For this specific application of DYNTOX dilutions are provided by the combined FDM, LDM, and FLOWMOD modeling system for any combination of diluting river flows and effluent flows specified continuously at hourly intervals over a 70 year simulation period. This application of DYNTOX is somewhat unique in that ambient and effluent water quality constituent concentrations are probabilistically generated in a Monte Carlo manner. Combination of deterministic continuous flows and probabilistic concentrations still results in a statistical description of resulting constituent concentration similar to those obtained by either complete continuous simulation or Monte Carlo simulation.

The approach taken for the review of the DYNTOX modeling component was to conduct a first principles review, while also taking into account comments and concerns raised the CVRWQCB. This resulted in an initial memorandum of comments and questions from Tetra Tech to SRCSD. Following a response from SRCSD a second memorandum of outstanding comments was sent by Tetra Tech to SRCSD. Response by SRCSD to the second memo resolved the most important issues and a final DYNTOX resolution memo was provided by Tetra Tech to CVRWQCB stating this. Specifically this memo (Jon Butcher, September 7, 2007, concludes that many of the technical shortcomings of the analysis amount to conservative assumptions or are unlikely to have significant impacts, such that risk is unlikely to be underestimated. These three memoranda are included in attachment A. The two SRCSD responses are included in the electronic documents file previously provided to SRCSD.

6. Conclusions and Recommendations

The general conclusion from this review is that the dynamic modeling study was conducted in a sound and scientifically defensible manner. The study is unique in the extent of field dye investigations use to support the central FLOWMOD diffuser model. The linked dynamic modeling system is capable for providing a probabilistic representation of receiving water quality conditions including frequency and duration of periods when standards are exceeded.

The only perceived short coming of the dynamic modeling system, from a regulatory perspective, could be that the complexity of the system of linked models and the proprietary status of a number of model components will prevent its transmittal to and use by regulatory agency personnel. Presuming this transmittal was not a specific requirement of the study, any further issues that might be addressed by modeling will require the cooperation and efforts of Sacramento Regional County Sanitation District and its modeling consultants.

7. References

Flow Science Incorporated (2006a). Results of Longitudinal Model of Worst Case Reverse Flow Events. FSI 048087. August 18, 2006.

Flow Science Incorporated (2006b). Model Sensitivity Analysis for FLOWMOD Simulations of the SRCSD Effluent Discharge to the Sacramento River at Freeport, CA. FSI 034023. September 15, 2006.

Flow Science Incorporated (2006c). Results of the October 2005 Dye Study of the SRCSD Effluent Discharge to the Sacramento River at Freeport, California. FSI 054076. October 16, 2006

Flow Science Incorporated (2006d). Model Verification Results for FLOWMOD Simulations of SRCSD Effluent Discharge to the Sacramento River at Freeport, October 2005 Field Study. FSI 054076. October 23, 2006.

Flow Science Incorporated (2006e) Results of the June 2006 Dye Study of Effluent Discharge to the Sacramento River at Freeport. FSI.054076. November 17, 2006.

Flow Science Incorporated (2006f). Final Review Draft - Model Verification Results for FLOWMOD Simulations of SRCSD Effluent Discharge to the Sacramento River at Freeport, June 2006 Field Dye Study. FSI.054076. November 17, 2006.

Flow Science Incorporated (2007a). Results of the November 2006 Dye Study of Effluent Discharge to the Sacramento River at Freeport, California. FSI 054076. May 31, 2007.

Flow Science Incorporated (2007b). Model Verification Results for FLOWMOD simulations of SRCSD Effluent Discharge to the Sacramento River at Freeport, November 2006 Field Dye Study. FSI.054076. June 11, 2007.

Sacramento Regional County Sanitation District (2003). Sacramento Regional Wastewater Treatment Plant 2020 Master Plan, Draft Environmental Impact Report, August 2003.

Attachment A. Intermediate Memoranda from Tetra Tech to CVRWQCB

Tetra Tech, Inc.
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Memorandum

Date: October 26, 2006

From: John Hamrick, Ph.D., P.E., Jon Butcher, Ph.D., P.H.

To: James D. Marshall, P.E.
Senior Water Resources Control Engineer
Central Valley Regional Water Quality Control Board
11020 Sun Center Dr. Suite 200
Rancho Cordova, CA 95670

Cc: John Craig, David Carlson

Subject: Review of DYNTOX Modeling Component of the Sacramento Regional CSD Dynamic Modeling Study

Introduction

As part of Tetra Tech's ongoing review of Sacramento Regional CSD's dynamic modeling study, to support the Draft Environmental Impact Report (Draft EIR) for the for the Sacramento Regional Wastewater Treatment Plant (SRWTP) 2020 Master Plan, this memorandum summarizes our review of the DYNTOX modeling component. The review as prepared by Dr. Jon Butcher of Tetra Tech.

Materials Reviewed

The following materials, provided in electronic form, were reviewed

DFT WQ modeling – Thermal Presentation (part 1& 2): Two part power point slide set with no date.

EIR_ Appendices F, G, H, and I – from Draft EIR: Appendix F, which describes modeling is dated July 2002

NDPES_B: Antidegradation Analysis for Proposed Wastewater Treatment Plant Modification dated February 2005

Letter from Karen Niiya to Patricia Leary dated 14 April 2005 summarizing Regional Board comments on modeling in EIS. File 2005_04_14NiiyaModelingMemo.doc

Data Used to Develop Statistical Distributions for Individual Constituents in SRCSD Effluent. Files SRCSD Effluent Distribution Plots Memo.doc and SRCSD Effluent Distribution Plots.doc

RWQCB Comments and SRCSD Responses: Three response Tables, ResponseTable1of3.doc, Response Table 2 of 3 reorganized.doc, ResponseTable3of3.doc

In addition, the following hard copy document was reviewed.

SRCSD Dynamic Modeling Workshop Support Document, April 2003.

Summary

The linked set of models used in the Sacramento EIR includes an application of DYNTOX to perform a statistical (Monte Carlo) simulation of the distribution of concentrations resulting from the discharge. The general procedure is described as combining a 70-year series of in-stream dilution flows (generated by the DYNFLO model) with statistical distributions of the effluent and upstream concentrations. Although the DYNTOX application procedure is not described in full detail in materials reviewed, the information available does raise some potential concerns with respect to correlation between flow and concentration and disaggregation of monthly flows to hourly.

Experience attempting to run DYNTOX 2 using observed flows and statistically generated effluent concentrations results in a warning message stating "You have specified a distribution type other than Constant, Linear Interpolation, Simple Markov, or Multiple Markov for one or more variables in your Continuous Simulation run. Since these variables will not reflect auto-correlation information, you should return to the menu and change these inputs." Thus it appears that a modified version was used that allowed the users to combine a continuous series of simulated dilution flows with statistically generated effluent flows, effluent concentrations, and upstream concentrations, which is the situation that DYNTOX 2 warns against. It was also stated that the DYNTOX code was modified to operate at a 1-hour time step, to provide multiple comparison points, and to update the ammonia representation to the current criteria recommendations. The revised code incorporating these modifications was not provided.

DYNTOX provides a rather primitive approach to Monte Carlo simulation that ignores potentially important serial and cross-correlations between time series. Further, the procedures for deriving the river flow and effluent discharge time series likely do not fully represent their cross-correlation, although the operational rules at the plant likely dampen this effect. These potential deficiencies seem most likely to impact the simulation of conditions associated with higher-flow, runoff events. Further, it seems likely that the errors introduced into the model are primarily of a conservative nature – that is, they will tend to over-estimate discharge impact by ignoring positive correlations between river flow, effluent flow, and river concentration. If the critical conditions are associated with base-flow, rather than event, conditions, the existing analysis may be adequate. However, one area of potential concern is the discharge of diverted effluent as river flow rises above the 14:1 ratio. If these diverted flows have higher than average concentrations, their associated risk might be under-estimated. Some further analysis would be appropriate to validate the model's performance by comparing the simulated distribution of mixed concentrations to observations obtained in the same month.

Recommendations

A more detailed description of the DYNTOX application procedure addressing issues in the complete review section of this memorandum should be requested. A review of the modified DYNTOX model code and associated input files is also recommended.

Complete Review

The linked set of models used in the Sacramento EIR includes an application of DYNTOX to perform a statistical (Monte Carlo) simulation of the distribution of concentrations resulting from the discharge. The general procedure is described as combining a 70-year series of in-stream dilution flows (generated by the DYNFLO model) with statistical distributions of the effluent and upstream concentrations. Unfortunately, the DYNTOX application procedure is not described in full detail. However, the information available does raise some potential concerns.

DYNTOX is a mixing model developed by LimnoTech for USEPA. The first version was released in 1985[1] to support wasteload allocations for toxics in streams and rivers, and the tool is referenced extensively in EPA's 1991 Technical Support Document for Toxics. An improved and updated version (DYNTOX 2) was created in 1995; however, USEPA never formally released the version 2 user's manual. The model was formerly distributed by USEPA's Center for Exposure Assessment Modeling (CEAM), but is no longer supported by CEAM. DYNTOX may, however, be obtained on request from LimnoTech. The model is written in Borland Turbo Pascal, and the last version distributed by USEPA will not run on most modern PCs without code recompilation.

DYNTOX provided three methods for evaluating the distribution of instream concentrations (continuous simulation, Monte Carlo simulation, and lognormal dilution modeling). The Monte Carlo simulation approach generates realizations from time series (such as effluent concentration) based on random sampling from a statistical distribution. The program operates Monte Carlo simulation at a simplified level, as cross-correlation between random variables (often important in real world situations) is not considered. In addition, the model does not provide capabilities for properly combining continuous simulation and Monte Carlo simulation: For example, if one attempts to run DYNTOX 2 using observed flows and statistically generated effluent concentrations, the program pops up a message stating "You have specified a distribution type other than Constant, Linear Interpolation, Simple Markov, or Multiple Markov for one or more variables in your Continuous Simulation run. Since these variables will not reflect auto-correlation information, you should return to the menu and change these inputs." It is suspected that this limitation was not noted in version 1 of the model.

For the EIR, the DYNTOX code is stated to have been modified to operate at a 1-hour time step, to provide multiple comparison points, and to update the ammonia representation to the current criteria recommendations. Unfortunately, the revised code has not been provided. However, it appears that a version was used that allowed the users to combine a continuous series of simulated dilution flows with statistically generated effluent flows, effluent concentrations, and upstream concentrations, which is the situation that DYNTOX 2 warns against.

Why is this an issue? Consider the case in which there is a strong positive correlation between effluent loading and upstream dilution flow. That would mean that high discharges were most likely to occur in conjunction with high dilution flows, and simulation without representation of

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[1] LimnoTech. 1985. Dynamic Toxics Wasteload Allocation Model (CYNTOX), User's Manual. Prepared for USEPA Monitoring and Data Support Division. LimnoTech, Inc., Ann Arbor, MI.

the correlation would over estimate the risk (expressed as the frequency of occurrence of unacceptable high concentrations). On the other hand, a negative correlation between effluent loading and upstream dilution flow would result in an under-estimation of risk. Similarly, ignoring a positive correlation between upstream concentration and effluent loading would cause an under-estimation of risk.

Exact details of the Sacramento DYNTOX application are incompletely documented. River flows derive ultimately from the PROSIM model, which provides predictions of monthly flow volume. The FDM model is then used to disaggregate the monthly flows and combine them with tidal forcing to produce an hourly flow series. As shown in Figure 3-6 of the Water Quality Modeling Technical Memorandum, this monthly-to-hourly disaggregation procedure results in a situation in which high flow, event-driven conditions are not well represented in the mixing model. However, base-flow conditions do appear to be well represented.

The model also requires hourly effluent flows, which are partially tied to the in-stream flows. The procedure began with projection of monthly average effluent flow rates. A "typical" intra-day pattern of discharges was then imposed on the monthly average rate. The series was then further modified to reflect operational rules and permit constraints at the plant:

- During times when no reverse-flow events occur (as predicted by the FDM), effluent flow was discharged to the river directly.
- When the estimated Sacramento River flow rate fell below the 14:1 flow ratio, the base effluent flow was simulated as being sent to temporary storage in diversion basins.
- If effluent was in storage, when the simulated Sacramento River flow rate exceeded the 14:1 ratio a post-diversion discharge rate was calculated as the base effluent flow rate plus flow out of the diversion basin, calculated as the volume of effluent contained in the diversion basin divided by the shorter of the length of time until the river flow rate again fell below the 14:1 ratio or 12 hours.
- The effluent discharge rate was constrained to not exceed the 14:1 flow ratio at any time.
- The effluent discharge rate was not allowed to exceed the hydraulic capacity of the discharge system.

This approach indicates that the correlation between instream dilution and effluent discharge rate is partially accounted for. The ultimate linkage, however, is at the monthly scale of PROSIM. Just as the FDM is not able to reproduce short term variability in the river hydrograph the approach will also have problems in simulating short-term variability in effluent flow. The imposition of a "typical" daily pattern on monthly average flow means that influence of precipitation events on effluent discharge is not accounted for. This is of some concern because the service area contains 10 square miles of combined sewer system in Sacramento. However, the operational conditions at the plant (including effluent diversion storage and a cap on the outfall hydraulic capacity) likely serve to damp this variability.

In contrast to dilution, river and effluent water quality were generally simulated by random Monte Carlo sampling from statistical distributions, and are thus represented as uncorrelated with flows. The Technical Memorandum (p. 4-7) states "If statistically significant...relationships with river flows were evident for a parameter...distributions were expressed as a function of time an/or flow, based on the results of multiple regression analysis." However, Table 4-4 shows that this procedure was used only for temperature (river flow and effluent) and hardness (river flow only). Despite this, Table 4-3 shows significant correlation between flow and pH, TSS, and copper, while correlations between flow and hardness and NH_4 were not significant. Results are not shown for other parameters. For example, the natural logarithm of copper concentration in the river has a high positive correlation coefficient to the natural logarithm of flow - as might be expected if the copper derives from surface wash-off events – but the DYNTOX application simulates copper as log-normally distributed, independent of flow. This means that the Monte Carlo simulation will not represent the tendency of higher river copper concentrations to be associated with higher river flows.

The simplified DYNTOX approach also does not account for (nor does the Technical Memorandum evaluate) the likely presence of autocorrelation (persistence) in the water quality time series. While this issue is not explicitly addressed, it is likely that DYNTOX has introduced some artificial serial correlation. Specifically, most versions of DYNTOX used the PASCAL-supplied random number generator. Like many system-supplied random number generators, this generator is believed to contain sequential correlation on successive calls, which is one reason that DYNTOX Monte Carlo simulations tend to converge more slowly than would be expected from input specifications. This can be remedied by use of more sophisticated random number generating techniques.

In summary, DYNTOX provides a rather primitive approach to Monte Carlo simulation that ignores potentially important serial and cross-correlations between time series. (In more sophisticated applications, this can be remedied by generating multiple time series simultaneously using a full covariance matrix.) Further, the procedures for deriving the river flow and effluent discharge time series likely do not fully represent their cross-correlation, although the operational rules at the plant likely dampen this effect.

These potential deficiencies seem most likely to impact the simulation of conditions associated with higher-flow, runoff events. Further, it seems likely that the errors introduced into the model are primarily of a conservative nature – that is, they will tend to over-estimate discharge impact by ignoring positive correlations between river flow, effluent flow, and river concentration. If the critical conditions are associated with base-flow (rather than event) conditions, the existing analysis may be adequate. However, one area of potential concern is the discharge of diverted effluent as river flow rises above the 14:1 ratio. If these diverted flows have higher than average concentrations, their associated risk might be under-estimated. Some further analysis might be needed to validate the model's performance by comparing the simulated distribution of mixed concentrations to observations obtained in the same month. A review should also be undertaken of the modified model code and associated input files.

SRCSD response to this memorandum contained in the following PDF format documents in the electronic document file

2-23-07_Response to RB Cover Letter.PDF – Cover letter for SRCSD response to comments on Dyntox modeling (SRCSD_Dyntox_Review 10-26-06.doc). Actual response in following document. Also see supporting material submitted under SRCSD February 2007 Submission

2-23-07_Resp to TetraTech_FinalVersion.PDF – Cover letter for SRCSD response to comments on Dyntox modeling (SRCSD_Dyntox_Review 10-26-06.doc)

Tetra Tech, Inc.
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Memorandum

Date: May 8, 2007

From: John Hamrick, Ph.D., P.E., Jon Butcher, Ph.D., P.H.

To: James D. Marshall, P.E.
Senior Water Resources Control Engineer
Central Valley Regional Water Quality Control Board
11020 Sun Center Dr. Suite 200
Rancho Cordova, CA 95670

Cc: John Craig, David Carlson

Subject: Review of DYNTOX Modeling Component of the Sacramento Regional County Sanitation District Dynamic Modeling Study

Introduction

Tetra Tech provided comments on the Sacramento Regional Wastewater Treatment Plant Dynamic Modeling Study by memorandum dated 26 October 2006. The Sacramento Regional County Sanitation District (SRCSD) provided a response to these comments on 23 February, 2007. The responses resolve some of the issues raised in Tetra Tech's October memorandum, but leave various others unresolved. Dr. Jon Butcher's comments on theses issues follow.

Re: Response to Tetra Tech Comment 1

We raised questions relative to whether the procedures for deriving the river flow and effluent discharge time series adequately considered the potential cross-correlation between these flows. In response, SRCSD first clarified that the effluent flow were *not* statistically generated. Rather, they were based on assumptions of a constant mean monthly effluent flow rate with imposition of a typical diurnal pattern: "The hourly diurnal variation of effluent flow rate…was taken to be constant for all days of all years… The mean monthly effluent flow rates were similarly taken as a constant for all years…" Results were then modified through application of SRCSD operational rules for discharge and diversion based on Sacramento River flow rates.

Based on this clarification, we do not, as previously thought, have a situation in which the cross-correlation between river flow and effluent flow might be misrepresented. Rather, such potential correlation is ignored altogether, except as realized through the application of the operational rules.

In response to Comment 3, SRCSD states "the correlation between the river and effluent flow rates at lower river flow rates was fully accounted for using the SRWTP's operating rules", and "monthly average effluent flow rates...were not adjusted in response to individual wet weather events...[but] the effect of this assumption is small and does not affect the frequency with which water quality criteria or thresholds are exceeded." SRCSD also notes that "while some correlation exists between river flow rates and effluent flow rates during high river flow periods, the correlation is relatively weak" due to the cap on the hydraulic discharge capacity at the plant and attenuation of high inflows by storage and capacity of the collection and conveyance systems.

It is not really the case that the low flow correlation is "fully accounted for" by incorporation of the operating rules. The operating rules result in a shifting of flow patterns during specific river flow conditions, but do not address any potential correlation when the river-to-effluent flow ratio is just above the 14:1 ratio. However, this is not likely to be a significant source of error. Indeed, ignoring the residual correlation is likely to be a conservative assumption if there is a positive correlation between effluent discharge and instream dilution capacity.

Of greater concern is the clarification that the effluent flows are not represented by any statistical procedure, but follow a constant pattern. Inherent in the nature of the analysis is the need for estimation of the frequency of rare events. Ignoring the variance component in the effluent flows could thus potentially bias the estimates of excursion frequencies.

Unlike discharge, effluent concentration is represented by a statistical distribution. SRWTP constituent load thus also has a statistical distribution (resulting from the constant flow pattern times the randomized concentration). The distribution of the effluent concentration is assumed to be independent of both effluent discharge and river flow. A relevant question is whether the resulting time series realization of effluent loads provides an accurate statistical representation of the actual load series, including any correlation to instream dilution capacity. A comparison of observed instantaneous loads to the simulated distribution of loads would be informative and should be supplied.

From a decision perspective, these issues are really only of concern if they lead to a misestimation of excursion frequencies. A case in which excursion frequencies could be underestimated might occur if there was significant correlation between effluent concentration and effluent flow, resulting in an underestimation of the variability of effluent load.

Re: Response to Tetra Tech Comment 2

SRCSD's clarifications appear to resolve this comment. Revisions to the DYNTOX code were documented, and the model code supplied.

Re: Response to Tetra Tech Comment 3

One focus of this comment was the potential underestimation of high river flow rates. The response acknowledges that "high river flow rates that would result from individual storm events lasting less than a month in duration are 'averaged' into the monthly flow rate." SRCSD contends that this is not a problem, because it is low flows that represent the critical condition. Tetra Tech's original comment concluded that such errors "are primarily of a conservative nature." The response reiterates this, stating "the inability of the DYNTOX analysis to capture the highest river flows leads to a conservative result." We seem to be in agreement on this point, and no further response is needed.

Tetra Tech's comment also raised a potential concern over diverted flows, noting that if these "diverted flows have higher than average concentrations, their associated risk might be under-estimated." In response, SRCSD states that "inflows to the diversion basins during periods of low river flow...consist of fully-treated effluent identical to undiverted flows... Thus, diverted effluent was modeled as having a concentration distribution identical to undiverted effluent." This sounds reasonable, but is not fully responsive. The issue ties back to the issue of potential correlation between effluent concentration and effluent flow. If there is a negative correlation between effluent concentration and effluent flow (such as would occur when load remains relatively steady as flow decreases), then their remains a possibility that the water that is diverted during drought conditions could have higher concentrations, in turn leading to higher risk of excursions when the diverted water is discharged as river flow rises above the 14:1 flow ratio. It seems somewhat unlikely that this issue is a significant one. However, it would be advisable for SRCSD to provide documentation to show that the concentrations of diverted effluent do indeed follow the same concentration distribution as undiverted flows.

Re: Response to Tetra Tech Comment 4

Tetra Tech's original comment asked why river temperature and hardness were simulated as correlated to flow, while river pH, TSS, and copper were not – despite the fact that statistically significant correlations were shown in Table 4-3. The response states that river pH was modeled as correlated with the 12-hour average river flow rate and river alkalinity. That does reproduce the correlation, but appears to contradict Table 4-4, where river pH is shown as simulated by a normal distribution. With the code now available, it is clear that the pH simulation does depend on flow. Thus, for pH, the only issue is that an appropriate footnote should be provided for Table 4-4.

The response does *not* address the correlations between copper and flow and between TSS and flow, both of which are shown to be statistically significant in Table 4-3. Instead, the response talks about the lack of correlation between dissolved metals and hardness and between pH and ammonia. These assumptions were never in question.

Both dissolved and total copper were found to have statistically significant correlations with flow and TSS. These correlations are apparently not addressed in the model. However, because the correlations are positive, the lack of representation of correlation would appear to be conservative in that it would not tend to underestimate toxicity at low flow concentrations.

Re: Response to Tetra Tech Comment 5

The first point in this comment was on potential serial correlation in river and effluent concentrations. This could effect the calculation of excursions of the 4-day average concentration. SRCD responded that "no local data exist to evaluate whether or not a serial correlation is present", that the ITRC didn't believe that autocorrelation would have "a significant effect on data handling or analysis", and that other conservative assumptions mean that "the effect of assuming that autocorrelation does not exist is expected to be insignificant." This response seems insufficient, and is based purely on speculation. If data are lacking, it would seem appropriate to directly evaluate the potential impacts of assuming various levels of autocorrelation in the model, rather than just assuming the effect would be "insignificant." While it is true that continuous data sets for metals concentrations at short time spans are rare, some insights into the potential degree of autocorrelation can be gained by examining continuous datasonde records of parameters such as turbidity or conductivity that are available for many sites.

The second part of the comment concerned potential weaknesses in the random number generator. The response clarifies that the revised DYNTOX model was compiled with Delphi 5, rather than TurboPascal, which was used for earlier versions. Delphi uses a 32-bit random number generator, superior to the 16-bit generator employed in TurboPascal. Further, examination of the code shows that an additional randomizing shuffle (RAN0) is employed to reduce the effects of spurious sequential correlation. Given these clarifications and the tests cited in the response, the random number generator appears fully acceptable.

Re: Response to Tetra Tech Comment 6

At the end of our previous comments, Tetra Tech stated that "some further analysis might be needed to validate the model's performance by comparing the simulated distribution of mixed concentrations to observations obtained in the same month." SRCD responded that "As a Monte Carlo model, the results of the DYNTOX analysis should not be expected to produce results that are identical, or even necessarily similar, to field data for specific periods that are short relative to the total simulation period of the model" and "it would not make sense to validate model results against one month of field observations."

We agree with the specific statements in the response, but feel they do not fully address the issue and represent a misinterpretation of our comment. We certainly did not intend to imply that the model should or could be validated against one month of field observations. Rather, consideration of month is important because the simulation model has a monthly component and any comparison of model and data must take month into account. The purpose of the comment was to suggest a check for consistency between what the model predicts and what is observed ("validate" was a poor choice of wording for this comment, as formal model validation is not what was intended). It is fine to contend that "model outputs … fully characterize the long-term statistical character of constituent concentrations downstream of the diffuser", but why not test this presumption further? If the model does indeed "fully characterize" performance then the distribution of available observed concentrations should be consistent (or, rather, not inconsistent) with model simulated results. For example, a two-sample Kolmogorov-Smirnov test could be applied to evaluate whether the available observations are indeed consistent with the statistical distribution produced by the model.

SRCSD response to this memorandum contained in the following PDF format documents in the electronic document file

7-3-07 SRCSD Response to Comments.pdf - SRCSD response to comments on Dyntox modeling review 2 (Tetra Tech Memo SRCSD Dyntox Review2_5-8-07.doc)

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MEMORANDUM

To: John Hamrick **Date:** September 7, 2007

From: Jonathan Butcher **Project:** Sacramento Diffuser

Subject: Review of Additional Response to Comments on DYNTOX Modeling Component of the Sacramento Regional County Sanitation District Dynamic Modeling Study

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Tetra Tech provided comments on the Sacramento Regional Wastewater Treatment Plant Dynamic Modeling Study by memorandum dated 26 October 2006. The Sacramento Regional County Sanitation District (SRCSD) provided a response to these comments on 23 February, 2007. Tetra Tech commented on the response on 8 May 2007, and SRCSD provided additional responses on 3 July 2007. These additional responses resolve the more significant outstanding issues. A review of the current status of responses is provided below.

Re: Tetra Tech Comment 1

The significant issues regarding this comment have generally been resolved. We agree that many of the technical shortcomings of the analysis amount to conservative assumptions or are unlikely to have significant impacts, such that risk is unlikely to be underestimated. The response contending that variance in effluent flow rates is included in the model is not quite correct – the model includes monthly and diurnal flow patterns and operating rules, but does not evaluate variability about these components. However, the clarification that effluent discharge is strictly limited by the operating rules and the hydraulic capacity of the pumps minimizes the importance of this issue, and the approach is acceptable.

SRCSD provided the requested reanalysis of correlations between pollutant concentrations and flow, and demonstrated that the relationships were weak, supporting the existing analysis. No response was made to the suggestion that a comparison of the distribution of observed instantaneous loads to the simulated distribution be provided.

Re: Tetra Tech Comment 2

These issues were resolved in the previous round of comments.

Re: Tetra Tech Comment 3

The remaining issue under this comment concerned the relationship between effluent concentrations in diverted and undiverted flow and their relationship to flow. The additional response sufficiently demonstrates that these issues are not a major cause for concern.

Re: Tetra Tech Comment 4

These issues have been resolved by demonstrating that the existing analysis uses conservative assumptions; thus, remaining uncertainties in the approach will not lead to an underestimation of risk.

Re: Tetra Tech Comment 5

As requested, SRCSD examined available data on serial correlation in river and effluent concentrations. The DYNTOX model was then rerun to test the potential impacts of serial correlation. The additional runs successfully demonstrate that the impacts of serial correlation are minimal, and that the assumption of no serial correlation in the prior EIR analysis did not bias results.

Re: Tetra Tech Comment 6

In the previous clarification to this comment, Tetra Tech suggested that it would be useful to conduct a check for consistency between what the model predicts and what is observed for statistical distributions of concentrations. SRCSD declined to provide such a comparison, and instead provided an argument that the comparison "is not possible with available data, and would not provide as reliable a check for model consistency and appropriateness as is possible with other information collected within the plume." We disagree with various details of the case made by SRCSD; however, this is not a fatal flow for the study, as the comparison was raised only as a suggestion. Further, while a successful statistical comparison would lend further assurance to the results of the study, we recognize that for an unsuccessful comparison it might not be possible to resolve the impacts of data uncertainty from issues with the model itself.

Attachment B. Index of Electronic Document File for SRCSD Dynamic Modeling Review

Contents as provide to CVRWQCB on September 26, 2007.

Compiled by John M. Hamrick, Tetra Tech, Inc.

Correspondence (Transmittals, Comment and Response Memos)

2005_04_14_NiiyaModelingMemo.doc – CV Regional WQC Board comments on modeling in EIS dated April 14, 2005 (electronic copy received by Tt on 11/28/05)

SummaryofModels.doc – provided with Niiya Memo. Actual date and author uncertain (electronic copy received by Tt on 11/28/05)

ResponseTable1of3.doc
Response Table 2 of 3 reorganized.doc
ResponseTable3of3.doc
- these 3 documents provided with Niiya Memo. SRCSD response to Niiya memo. Actual date uncertain. (electronic copy received by Tt on 11/28/05)

DeliverableTable8-23-06.doc – list of deliverable to be provide by SRCSD in further response to April 14, 2005 Regional Board (Niiya) Memo (electronic copy received by Tt on 9/15/06)

Cover Letter 9-15-06.pdf – transmittal letter from SRCSD to CVRWQCB with following
FRWA SRCSD Report 8-18-06.pdf
Report Sensitivity Analysis 9-15-06.pdf
SRCSD Effluent Distribution Plots.doc
SRCSD Effluent Distribution Plots Memo.doc

DeliverableTable9-15-06.doc – list of deliverable to be provide by SRCSD in further response to April 14, 2005 Regional Board (Niiya) Memo (electronic copy received by Tt on 9/22/06)

Oct06_1_Cover letter and table.pdf – transmittal letter from SRCSD to CVRWQCB internally dated October 23, 2006 with following
Oct06_2_Final FSI Oct 2005 Dye Study Report.pdf
Oct06_3_Attachment A-B&C Data Report.pdf
Oct06_4_FLOWMOD Validation_October2005_.pdf
Oct06_5_FLOWMOD figures.pdf

SRCSD_Dyntox_Review 10-26-06.doc – Tt Review of Dyntox component of modeling submitted to CV Regional Water Quality Control Board (original submission name SRCSD_Dyntox_Review.doc)

InfoMemo 11-7-06.doc – Tt request for information on diffuser operational configuration and data from October 2005 dye study submitted to CV Regional Water Quality Control Board (original submission name InfoMemo.doc). Request data was provided in 9 excel spread sheets on November 14, 2006. The spread sheets are not included in this set of material.

Submittal Cover Letter 11-17-06.pdf – transmittal letter from SRCSD to CVRWQCB internally dated November 17, 2006 with following

Attachment A-BC Final June 06 Data Report.pdf
Attachment B Bathymetry June 06.pdf
Attachment C Velocity Profiles.pdf
FLOWMOD Validation June 06.pdf
FLOWMOD figures. Pdf
June 2006 Dye Study Report – Final.pdf

Deliverable Table 11-17-06.pdf – Revised deliverable table accompanying above letter

12-18-06 Response to RB.pdf – SRCSD response to email request from Tt via CVRWQCB regarding request for additional information on Oct 23, 2006 SRCSD submission. All Email images included.

2-23-07_Response to RB Cover Letter.PDF – Cover letter for SRCSD response to comments on Dyntox modeling (SRCSD_Dyntox_Review 10-26-06.doc). Actual response in following document. Also see supporting material submitted under SRCSD February 2007 Submission

2-23-07_Resp to TetraTech_FinalVersion.PDF – Cover letter for SRCSD response to comments on Dyntox modeling (SRCSD_Dyntox_Review 10-26-06.doc)

Tetra Tech Memo SRCSD Dyntox Review2_5-8-07.doc – Second round of Tt Review of Dyntox component of modeling submitted to CV Regional Water Quality Control Board (original submission name Tetra Tech Memo SRCSD Dyntox Review2.doc) specifically addressing response comments in preceding document: 2-23-07_Resp to TetraTech_FinalVersion.PDF

Cover Letter 6-11-07.pdf – transmittal letter from SRCSD to CVRWQCB internally dated June 11, 2007 with following

November 2006 dye study report plus appendices.pdf
November 2006 FLOWMOD_Validation_Fall2006_final.pdf

Deliverable Table 6-11-07.pdf – Revised deliverable table accompanying above letter

7-3-07 SRCSD Response to Comments.pdf - SRCSD response to comments on Dyntox modeling review 2 (Tetra Tech Memo SRCSD Dyntox Review2_5-8-07.doc)

Tetra Tech Memo SRCSD DNYTOX Review3_9-7-07.doc – Tetra Response to 7-3-07 SRCSD Response to Comments.pdf

NPDES Permit and EIR Reports

NPDES_B Antidegradation Analysis Report.pdf (electronic copy received by Tt on 12/02/05)

EIR_ Appendix F Water Modeling .pdf – from Draft EIR (electronic copy received by Tt on 12/02/05)

EIR_ Appendix SacRiver Background data.pdf – from Draft EIR (electronic copy received by Tt on 12/02/05)

EIR_ Appendix H ScreeningAnalysis .pdf – from Draft EIR (electronic copy received by Tt on 12/02/05)

EIR_ Appendix I Modeling Results – .pdf – from Draft EIR (electronic copy received by Tt on 12/02/05)

SRCSD September 2006 Submission

FRWA SRCSD Report 8-18-06.pdf – Longitudinal Dispersion Model Worst Case Event Analysis prepared by Flow Science, Inc internally dated 8/18/06

Report Sensitivity Analysis 9-15-06.pdf – FLOMOD diffuser model sensitivity analysis prepared by Flow Science, Inc internally dated 9/15/06

SRCSD Effluent Distribution Plots Memo.doc Data Used to Develop Statistical Distributions for Individual Constituents in SRCSD Effluent (electronic copy received by Tt on 9/22/06)

SRCSD Effluent Distribution Plots.doc - Data Used to Develop Statistical Distributions for Individual Constituents in SRCSD Effluent (electronic copy received by Tt on 9/22/06)

SRCSD October 2006 Submission

Oct06_2_Final FSI Oct 2005 Dye Study Report.pdf – Results of Oct 2005 field dye study. Flow Science, Inc report internally dated Oct 16, 2006

Oct06_3_Attachment A-B&C Data Report.pdf – Oct 2005 Dye Data report prepared by Brown and Caldwell and submitted to Flow Science internally dated Feb 2006

Oct06_4_FLOWMOD Validation_October2005_.pdf – MODFLOW validation using Oct 2005 dye data. Flow Science, Inc report internally dated Oct 23, 2006.

Oct06_5_FLOWMOD figures.pdf - Figures to accompany validation report. Flow Science, Inc report internally dated Oct 23, 2006

SRCSD November 2006 Submission

Attachment A-BC Final June 06 Data Report.pdf – June 2006 Dye Data report prepared by Brown and Caldwell and submitted to Flow Science with no internal date

Attachment B Bathymetry June 06.pdf - June 2006 Bathymetry plot by Fugro West for Flow Science with no internal date

Attachment C Velocity Profiles.pdf – Field observed velocity collected by Tenera Environmental for Flow Science, Inc.

FLOWMOD Validation June 06.pdf - FLOWMOD validation using June 2006 dye data. Flow Science, Inc report internally November 17, 2006

FLOWMOD figures. Pdf - Figures to accompany validation report. Flow Science, Inc report internally dated November 17, 2006

June 2006 Dye Study Report – Final.pdf - Results of June 2006 field dye study. Flow Science, Inc report internally dated November 17, 2006

SRCSD February 2007 Supporting Material

Attachment 2_11-15-04LttrtoRWQCB_Respon.pdf – Letter from SRCSD to CVRWQCB with response to comments made at meeting on 9/14/2004.

Attachment 2_Att 4 Model Assumptions.pdf – Flow Science comments/response presumably accompanying above letter

Attachement 3_SRWTP 2020 Master Plan WQ Modeling ITRC.pdf – May 2002 Independent Technical Review. Note that this document has been available to Tt since 2005 in hard copy. The ITRC is referenced in various correspondence.

Attachment 4_dt0702.zip – DYNTOX model code and associated files (NOT Include in this set of material)

SRCSD June 2007 Submission

November 2006 dye study report plus appendices.pdf - Results of November 2006 field dye study. Flow Science, Inc report internally dated May 31, 2007

November 2006 FLOWMOD_Validation_Fall2006_final.pdf - FLOWMOD validation using November 2006 dye data. Flow Science, Inc report internally dated June 11, 2007.

Miscellaneous Documents Included

DFT WQ modeling Thermal Presentation Part 1& 2.ppt - Power Points giving quick overview of modeling. (electronic copy received by Tt on 06/06/06)